

## CLAIMS

What is claimed is.

1           1.       A ball-limiting metallurgy (BLM) stack comprising:  
2           a metal adhesion first layer disposed above and on a metallization;  
3           a metal second layer disposed above and on the metal adhesion first layer;  
4           a metal third layer disposed above and on the metal second layer;  
5           an electrically conductive bump disposed above and on the metal third layer;  
6   and  
7           wherein at least one of the metal second layer and the metal third layer  
8   comprises copper.

1           2.       The BLM stack according to claim 1, wherein the metal adhesion  
2   first layer is selected from Ti, TiW, W, and Cr.

1           3.       The BLM stack according to claim 1, wherein the metal second  
2   layer comprises copper and the metal third layer is selected from a refractory metal,  
3   a metal-doped refractory metal, or a refractory metal alloy.

1           4.       The BLM stack according to claim 1, wherein the metal second  
2   layer comprises copper and the metal third layer is selected from a refractory metal,  
3   a metal-doped refractory metal, or a refractory metal alloy selected from Ni, Co, Pd,  
4   Pt, NiV, CoV, PdV, PtV, Ti, Zr, Hf, Cr, Mo, W, Sc, Y, La, and Ce in a solid-  
5   solution or stoichiometric ratio.

1           5.       The BLM stack according to claim 1, wherein the metal second  
2   layer comprises copper and the metal third layer is selected from a nitrided  
3   refractory metal, a nitrided metal-doped refractory metal, or a nitrided refractory  
4   metal alloy selected from Ni, Co, Pd, Pt, NiV, CoV, PdV, PtV, Ti, Zr, Hf, Cr, Mo,  
5   W, Sc, Y, La, and Ce in a solid-solution or stoichiometric ratio.

1           6.       The BLM stack according to claim 1, wherein the metal third layer  
2 comprises copper, and wherein the metal second layer is selected from a refractory  
3 metal, a metal-doped refractory metal, or a refractory metal alloy.

1           7.       The BLM stack according to claim 1, wherein the metal third layer  
2 comprises copper and the metal second layer is selected from a refractory metal, a  
3 metal-doped refractory metal, or a refractory metal alloy selected from Ni, Co, Pd,  
4 Pt, NiV, CoV, PdV, PtV, Ti, Zr, Hf, Cr, Mo, W, Sc, Y, La, and Ce in a solid-  
5 solution or stoichiometric ratio.

1           8.       The BLM stack according to claim 1, wherein the metal third layer  
2 comprises copper and the metal second layer is selected from a nitrided refractory  
3 metal, a nitrided metal-doped refractory metal, or a nitrided refractory metal alloy  
4 selected from Ni, Co, Pd, Pt, NiV, CoV, PdV, PtV, Ti, Zr, Hf, Cr, Mo, W, Sc, Y,  
5 La, and Ce in a solid-solution or stoichiometric ratio.

1           9.       The BLM stack according to claim 1, wherein the metal second layer  
2 comprises a copper layer and wherein the metal third layer comprises a copper stud

1           10.      The BLM stack according to claim 1, further comprising:  
2 an intermetallic layer disposed between the metallization and the electrically  
3 conductive bump.

1           11.      The BLM stack according to claim 1, wherein the electrically  
2 conductive bump comprises a tin-lead solder composition selected from Sn37Pb,  
3 Sn97Pb, and  $\text{Sn}_x\text{Pb}_y$ , wherein  $x+y$  total 1 and wherein  $x$  is in a range from about 0.3  
4 to about 0.99.

1           12.      A process comprising:  
2 forming a metallization over a substrate;

3           forming a metal adhesion first layer above and on the metallization;  
4           forming a metal second layer above and on the metal adhesion first layer;  
5           forming a metal third layer above and on the metal second layer;  
6           forming a solder bump above and on the metal third layer, and  
7           wherein at least one of the metal second layer and the metal third layer  
8 comprises sputtered copper.

1           13.     The process according to claim 12, forming a metal adhesion first  
2 layer further comprising:  
3           sputtering a composition over the metallization under conditions to impart a  
4 compressive stress in the metal adhesion first layer, wherein the composition is  
5 selected from Ti, TiW, W, and Cr.

1           14.     The process according to claim 12, forming the metal second layer  
2 and forming the metal third layer further comprising:  
3           sputtering a copper metal second layer over the metal adhesion first layer  
4 under conditions to impart a compressive stress therein; and  
5           sputtering the metal third layer under conditions to impart a compressive  
6 stress therein, wherein the metal third layer is selected from a refractory metal, a  
7 metal-doped refractory metal, or a refractory metal alloy.

1           15.     The process according to claim 12, forming the metal second layer  
2 and forming the metal third layer further comprising:  
3           sputtering the metal second layer over the metal adhesion first layer and  
4 under conditions to impart a compressive stress therein, wherein the metal third  
5 layer is selected from a refractory metal, a metal-doped refractory metal, or a  
6 refractory metal alloy; and  
7           sputtering a copper metal third layer over the metal second layer under  
8 conditions to impart a compressive stress therein.

1           16.     The process according to claim 12, forming the metal second layer  
2     and forming the metal third layer further comprising:  
3           sputtering a copper metal second layer over the metal adhesion first layer  
4     under conditions to impart a compressive stress therein; and  
5           plating a copper stud through a mask that is disposed over the metal second  
6     layer.

1           17.     The process according to claim 12, further comprising:  
2           forming an electrically conductive bump above and on the metal third layer.

1           18.     A process comprising:  
2           forming a copper pad over a metal-six (M6) metallization;  
3           sputtering a Ti metal adhesion first layer above and on the metallization;  
4           sputtering a metal second layer above and on the Ti metal adhesion first  
5     layer;  
6           forming a metal third layer above and on the metal second layer;  
7           forming a solder bump above and on the metal third layer, and  
8           wherein at least one of the metal second layer and the metal third layer  
9     comprises copper.

1           19.     The process according to claim 18, wherein sputtering a Ti metal  
2     adhesion first layer above and on the metallization comprises:  
3           sputtering a Ti composition over the metallization, wherein the Ti  
4     composition has a thickness in a range from about 500 Å to about 4,000 Å.

1           20.     The process according to claim 18, wherein sputtering a metal  
2     second layer and forming a metal third layer comprise:  
3           sputtering a NiV composition over the Ti metal adhesion first layer, wherein  
4     the NiV composition has a thickness in a range from about 1,000 Å to about 5,000  
5     Å; and

6           sputtering a Cu composition over the metal second layer, wherein the metal  
7   third layer has a thickness in a range from about 1,000 Å to about 5,000 Å.

1           21.    The process according to claim 18, wherein forming a metal third  
2   layer comprises:  
3           sputtering a NiV composition over the metal second layer, wherein the NiV  
4   composition has a thickness in a range from about 1,000 Å to about 5,000 Å, and  
5   wherein the metal second layer has a thickness in a range from about 1,000 Å to  
6   about 5,000 Å.

1           22.    The process according to claim 18, wherein forming a metal third  
2   layer comprises:  
3           electroplating a copper stud over the metal second layer, wherein the copper  
4   stud has a thickness in a range from about 5 micrometers to about 15 micrometers,  
5   and wherein the metal second layer has a thickness in a range from about 1,000 Å to  
6   about 5,000 Å.

1           23.    A system comprising:  
2           a substrate comprising an electrical device;  
3           a metallization pad disposed over the substrate;  
4           a ball-limiting metallurgy disposed over the metallization pad, the ball-  
5   limiting metallurgy comprising:  
6           a metal adhesion first layer disposed above and on the metallization pad;  
7           a metal second layer disposed above and on the metal adhesion first layer;  
8           a metal third layer disposed above and on the metal second layer;  
9           an electrically conductive bump disposed above and on the metal third layer;  
10          wherein at least one of the metal second layer and the metal third layer  
11   comprises copper; and  
12          a flip-chip disposed over the ball-limiting metallurgy.

1           24.     The system according to claim 23, wherein the flip-chip comprises a  
2 solder having a composition of about Sn37Pb, and wherein the electrically  
3 conductive bump comprises a solder having a composition of about Sn97Pb.

1           25.     The system according to claim 23, wherein the electrical device  
2 comprises a chip-scale package.

1           26.     The system according to claim 23, wherein the flip-chip comprises a  
2 chip-scale package.

1           27.     The system according to claim 23, wherein the electrical device  
2 comprises a chip-scale package and wherein the flip-chip comprises a chip-scale  
3 package.

1           28.     The system according to claim 23, further comprising:  
2 an intermetallic zone that substantially isolates the metal third layer from the  
3 electrically conductive bump.